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History and Overview of EGS4

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Most of this lecture comes from…

F. Bielajew, H. Hirayama, W. R. Nelson and D.W.O.R Rogers,
"History, overview and recent improvements of EGS4",
National Research Council of Canada Report PIRS-0436 (1994)
(also: KEK Internal 94-4 and SLAC-PUB-6499)

These reports can be obtained from the following websites

http://www.irs.inms.nrc.ca/inms/irs/irs.html
http://ccwww.kek.jp/kek/rad/egs4/egs.html
http://www-user.slac.stanford.edu/egs/

respectively

Why has the Monte Carlo method become so popular? *

* Note: Between 1983-88 there was a five-fold increase in Monte Carlo papers—particularly electron-photon transport

- Analytic methods tend to be ***prohibitive*** (but some very difficult problems have finally been solved using MC)
- Monte Carlo is somewhat ***intuitive*** (and several good books have now been written on the subject)
- Computers continue to get ***faster*** and ***cheaper***!!!

Reasons For Popularity of EGS

- ***Powerful*** – Based on well-understood physics
- ***Versatile*** – General-purpose electron-photon code
- ***Benchmarked*** – Extremely well-checked
- ***Open Architecture*** – Many outside contributors
- ***User-Supported*** – Workshops, large community
- ***Timely*** – A code needed by medical physicists
- ***Expert-friendly*** – Good documentation
- **FREE** – Non-commercial **licenses**

Codes That Preceded EGS

- Messel & Crawford
  Australia (1958-1970)

  First computer Monte Carlo for high-energy electromagnetic cascade showers

  Nice tables published in so-called ***Shower Book***

  Code not available at all

- Zerby & Moran
  ORNL (1962-1963)

  Motivated by Panofsky (construction of SLAC)

  Excellent MC engineering

  Code not available outside ORNL

ETRAN - Berger and Seltzer

- NIST (1964-present)
- Excellent physics and MC techniques
- Great ***benchmarking*** !!!
- Unknown to the high-energy physics community (originally a **low-E** code)
- Definitely not user-friendly
- History: **ETRAN** → **ITS** → **MCNP**

SHOWER – The Seed for EGS

- H. Nagel – Univ. Bonn (1963-1967)
- Ph.D. dissertation (1964)
- Cylinder-slab geometry (and hard coded)
- Data for lead and copper only
- Missing some important physics processes
- But…***readily available*** !!!
- Brought to SLAC by Nagel in 1966

Development of EGS3 (1970's)
(SLAC-HEPL collaboration)

- Cloned from Nagel's SHOWER program
- Energy range extended (0.1 MeV to few GeV)
- Any 100 elements (compounds & mixtures)
- **PEGS3** code for creating media input data
- New physics processes were added
- Changed to more efficient sampling techniques
- EGS3 popularity because of credibility,etc.
- Also, perfect timing…..the ***November Revolution*** !

Development of EGS4 (1980's)
(SLAC-KEK-NRCC collaboration)

- SLAC-KEK (Nelson & Hirayama) :
  Extended flexibility for high-energy accelerator applications
- NRCC (Rogers & Bielajew):
  - Tremendous low-energy benchmarking effort
  - Medical physics applications, detector response
  - Importance of electron step-size (ESTEPE)
- SLAC-265 report issued in December 1985
- ***PRESTA*** algorithm released in 1986

Description of the EGS4 Code

- EGS – *analog* Monte Carlo program
  - Physical process simulated as closely as possible
  - Variance reduction techniques not “built in
  - Good for fluctuation studies (detector response)
  - Disadvantage: ***Very time consuming*** !
- Can introduce importance sampling:

  CALL SHOWER (IQ,E,X,Y,Z,U,V,W,IR,WT)

  (normally WT=1.0 by default)
- PEGS4 code – created for efficiency reasons

PEGS4 – Preprocessor for EGS4

- Uses theoretical and empirical formulae
  - Determines cross sections, branching ratios, etc.
  - Creates output → ***fast*** look-up table for EGS4
- Run PEGS4 before running EGS4
  - But only ***once*** for each ***medium***
  - Save output on disk for later use by EGS4

Electron Processes in EGS4

- Bremsstrahlung: Z(Z+1)
  - $\theta_{brem} = mc^2/E$ (default)
  - Special θ_{brem} sampling version available (macro)
- δ-ray production
  - Møller (e^-e^-) and Bhabha (e^+e^-)
- Collision loss
  - Between discrete interactions
  - Restricted $dE/dx)_{col}$ (i.e., LET_Δ)
  - $dE/dx)_{rad}$ for soft x-rays (added to collision loss)
  - Density effect (Sternheimer-Berger-Seltzer model)
- Multiple scattering – uses Molière model
- Positron annihilation (at-rest & in-flight)

Photon Processes in EGS4

- Pair production: Z(Z+1)
  - $\theta_{pair} = mc^2/E$ (default)
  - Special θ_{pair} sampling version available (macro)
- Compton scattering (unbound)
- Coherent (Rayleigh) scattering
- Photoelectric effect
  - Excitation energy deposited locally
  - Special ***fluorescence*** version available
  - PE-angle sampling (macro) also available

Basic EGS4 - circa 1985

- Dynamic energy range – several TeV to
  - 1 keV (photons)
  - 10 keV (electrons)
- User must create ***geometry*** and ***scoring*** routines
  (Subroutines **HOWFAR** and **AUSGAB**)
- Changes in basic EGS4 code done with ***macros***
- User-designed possibilities include:
  - Transporting in E and B fields
  - Adding weighting-biasing techniques (splitting, Russian roulette)
  - Sampling incident spectrum and/or angular (or spatial) distributions
- Great code for the ***creative*** user !!! (but user must write the **User Code**)

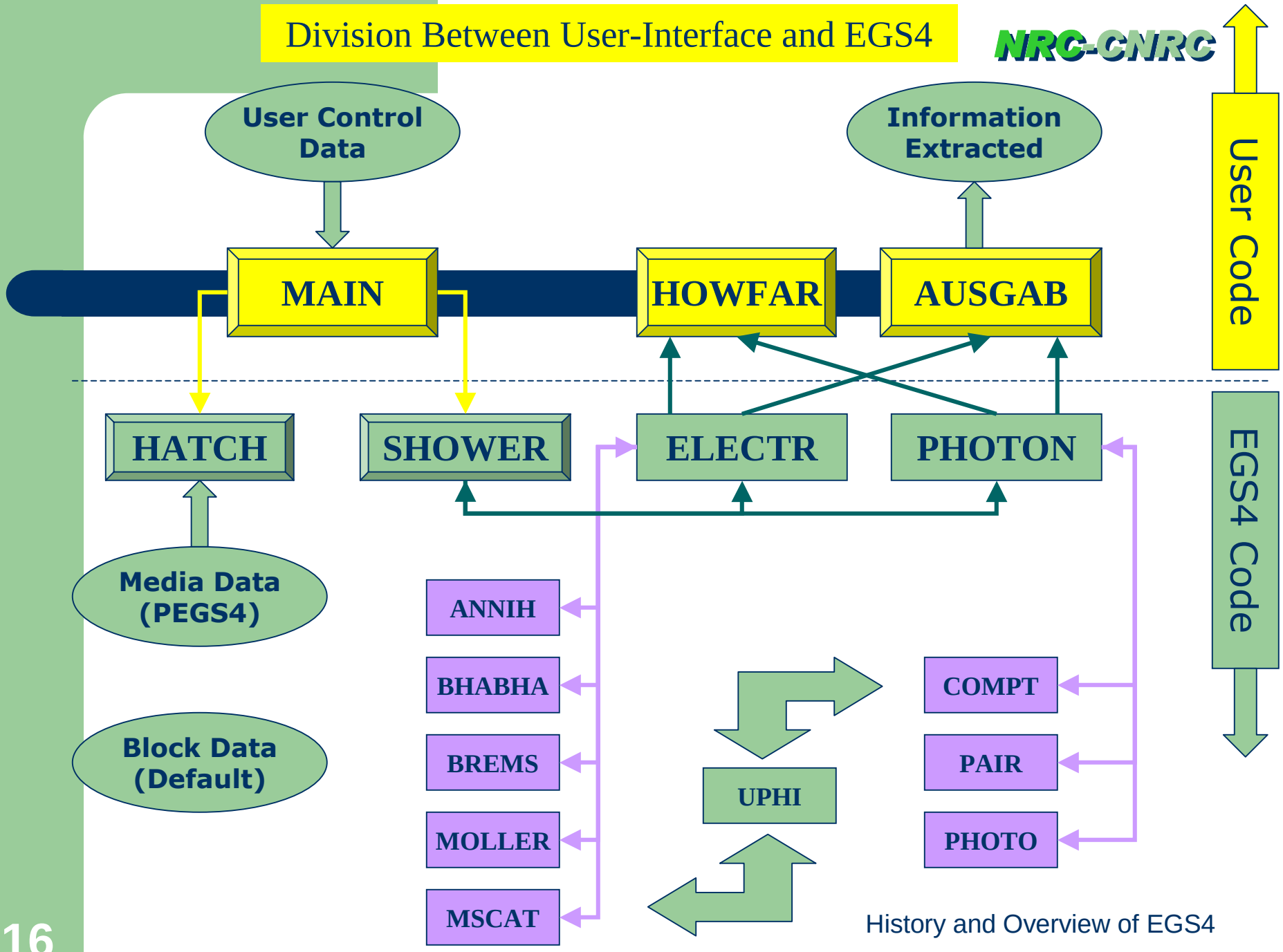
Special "User Codes" Available

- **UCSAMPL4** - Appendix 2 of SLAC-265 (the "manual")
- **DOSRZ** – Cylinder-slab geometry
- **XYZDOS** – Rectilinear-coordinate geometry
- **TUTOR1** thru **TUTOR7** – Tutorial codes (in Chapter 3)

The above come with the EGS4 Distribution Package (e.g., on the Web)

The User Code system works with EGS4 as follows…

Division Between User-Interface and EGS4



BEAM – A Sophisticated User Code

- ***BEAM*** was developed at the NRCC
- Ideal for clinical-accelerator geometries
- ***BEAM*** is a very good EGS4 User Code and is responsible for many journal papers
- An extensive workshop is offered

Many Improvements Since 1985

- Most improvements/enhancements are:
  - supplied with UNIX or PC distributions

  or

  - are obtained directly from author(s)
- Generally they are EGS4 options that:
  - must be "switched on" via flags

  and/or

  - are macros that are inserted in the User Code
- Full description given in Bielajew et al (NRC-PIRS-0436)

Improvements/Enhancements Fall Into Three Categories

- Physics Modeling
- Development of Tools and Techniques
- Systems and other Support

Physics Modeling

- PRESTA
- Angle sampling
- Fluorescence
- Electromagnetic fields
- Polarization
- Doppler Broadening
- Compton binding
- Electron-impact ionization
- Improved cross sections
- Single scattering

Development of Tools and Techniques

- Forced interactions
- Range rejection
- Bremsstrahlung splitting
- Long-sequence random numbers
- Graphics tools
- Geometry User Codes

Systems and other Support

- New platforms (UNIX, Linux, PC)
- EGS Listserv facility
- User Groups (in France, England, Japan…)
- EGS courses and workshops
- The ***EGS Web Page…***

http://www.slac.stanford.edu/egs/

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Welcome to the Electron Gamma Shower (EGS) Web Page

Artwork by Michael Sharpe

The EGS computer code system is a general purpose package for the Monte Carlo simulation of the coupled transport of electrons and photons in an arbitrary geometry for particles with energies from a few keV up to several TeV. Some have referred to the EGS code as the *de facto* gold standard for clinical radiation dosimetry. The history and an overview of EGS code system is documented in the report NRC-PIRS-0436 (pdf or postscript). Click here for a free copy of Adobe's Acrobat Reader (for printing/viewing PDF files).

The main intent of this web site is to facilitate the distribution and installation of the EGS computer code system. This web site also serves as a means of communicating technical information, conference and workshops announcements, and other information that may be of interest to the EGS user community. Click here for more information about this web site.

The HenHouse

- Add-ons and User Applications
- Announcements and Other News
- Books for the radiation transport specialist
- Bug Alerts
- Compilers, Tools, and Other Utilities
- EGS List Server
- Frequently Asked Questions (FAQ)

….move down the page a little further

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- Frequently Asked Questions (FAQ)
- Manuals *etc...*
- Source Code (standard distribution)

Other EGS Web Sites and Information

- 3D graphics display of EGS4 showers using VRML
- EGS-Nova: An Adaptation of EGS in C/C++
- EGS4 timing studies on various computers. Web page maintained by Alan DuSautoy. Please send additional timing studies to Alex F. Bielajew .
- An EGS4 primer by Alex F. Bielajew .
- KEK EGS Web Site (japan).
- National Research Council of Canada (NRC)
  - BEAM: A Monte Carlo Simulation System for Modelling Radiotherapy Sources
  - List of publications from the NRC Ionizing Radiation Standards Group
- The UK Monte Carlo Neutron, Electron, Gamma User Group

A Bit of This and That

- MCNP radiation transport code web page. A Visual Editor for MCNP.
- Nuclear Energy Agency (NEA) Data Bank
- NIST Physical Reference Data (e.g., CODATA recommended values of the fundamental physical constants)
- On-line Journals and Other Publications
- PEREGRINE Project Web page -- a M.C. tool for accurate radiation therapy dose calculations.
- PNNL Biological Effects of Radiation and Chemicals (BERC) website.
- Professional Societies and Other Organizations
- Radiation Safety Information Computational Center (RSICC) at Oak Ridge National Laboratory.
- PubMed search service with access to over 9 million citations from MEDLINE.

HowHouse Reactors (mahematters)

Click on *manuals, etc…*

EGS Manuals and Documentation

The EGS4 code system is documented in *The EGS4 Code System*, by W.R. Nelson, H. Hirayama, and D.W.O. Rogers, SLAC-265 (1985). An Adobe PDF version of this report can be downloaded from http://www.slac.stanford.edu/pubs/slacreports/slac-r-265.html To obtain a printed copy of the EGS4 manual, write to W. Ralph Nelson at

Stanford Linear Accelerator Center
P.O. Box 4349
Stanford, CA 94309

and ask for SLAC-265. **Be sure to include a brief description of what you plan to do with EGS.**

For your convenience, SLAC-265 appendices 2 through 5 have been converted to HTML and made accessible here.

- SLAC-265 Appendix 2: EGS4 User Manual in HTML. (61 kb)
- SLAC-265 Appendix 3: PEGS4 User Manual in HTML.(78 kb)
- SLAC-265 Appendix 4: EGS4 User Guide to Mortran3 in HTML.(36 kb)
- SLAC-265 Appendix 5: EGS4 System Considerations in HTML. A bit dated, but you may still find it useful.(26 kb)

Links to a few more EGS related documents are provided below. Since these files are fairly large, please download them during off hours (i.e., from 6 pm to 8 am PST). Additional EGS information and documents can be found on the NRC Ionizing Radiation Standards group (Canada) web page.

Mortran

- *Advanced Mortran3*
  W Ralph Nelson. ps (176 kb) or pdf (145 kb)
- *Elementary Mortran3*
  W Ralph Nelson. ps (145 kb) or pdf (120 kb)

History, Installation, and Use

- *EGS4 in '94 A Decade of Enhancements*
  W.R. Nelson, A.F. Bielajew, D.W.O. Rogers, and H. Hirayama ps (1926 kb) or pdf (298 kb)
- *History, overview and recent improvements of EGS4*
  A.F. Bielajew, H. Hirayama, W.R. Nelson, and D.W.O. Rogers. ps (306 kb) or pdf (295 kb)
- *HOWFAR -- How to code geometry*
  W Ralph Nelson. ps (2188 kb) or pdf (337 kb)
- *HOWFAR and HOWNEAR: Geometry Modeling for Monte Carlo Particle Transport*
  Alex F Bielajew. pdf (565 kb)
- *How to manage the EGS4 system*
  Alex F Bielajew. ps (193 kb) or pdf (178 kb)
- *Running EGS4 on other machines*
  Alex F Bielajew. ps (386 kb) or pdf (319 kb)

PEGS4 (cross sections)

- *PEGS4--Data sets for different media*
  W Ralph Nelson. ps (593 kb) or pdf (212 kb)

Other

- *Efficiency statistics and sampling*
  Alex F Bielajew ps (216 kb) or pdf (209 kb)
- *Electron Monte Carlo simulation*
  Alex F Bielajew and David W O Rogers ps (379 kb) or pdf (236 kb)
- *Graphics!*
  Alex F Bielajew ps (97 kb) or pdf (108 kb)
- *Monte Carlo Modeling in External Electron-Beam Radiotherapy: Why Leave It to Chance?*
  Alex F Bielajew ps (2156 kb) or pdf (318 kb)
- *Photon Monte Carlo simulation*

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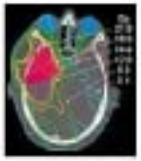
SPIRES

A national laboratory operated by Stanford University **for the** Department of Energy **and home of the** first U.S. Web site.

SLAC Software Finds Place in Cancer Battle



EGS (for Electron-Gamma Shower) a software program developed at SLAC, originally to assist in calculating shielding needs, is increasingly being used by the medical community to help plan x-ray cancer therapy. This program, affectionately known as 'eggs,' can simulate the paths and energy deposits of particles in an endless variety of materials and geometries. Enhancements to the simulation tool allow medical physicists to design x-ray beam configurations specific to individual patients thus ensuring that as much energy as possible is concentrated on the tumor and not on nearby healthy tissues.

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Conferences, Workshops, and Meetings

SLAC sponsored events are listed on our Conferences page. The SLAC Seminars database lists meetings, colloquia and seminars of interest to the broad high-energy physics community. Check the SPIRES Conferences database for physics conferences elsewhere.

Also,…**click** on the *Virtual Visitor Center* and then *Applications* to learn about how EGS is being used in Radiation Treatment Planning

http://www2.slac.stanford.edu/vvc/applications/egs4/egs.html

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APPLICATIONS

Treating Cancer with Radiation . . .

. . . and improving our techniques with the EGS Computer Code.

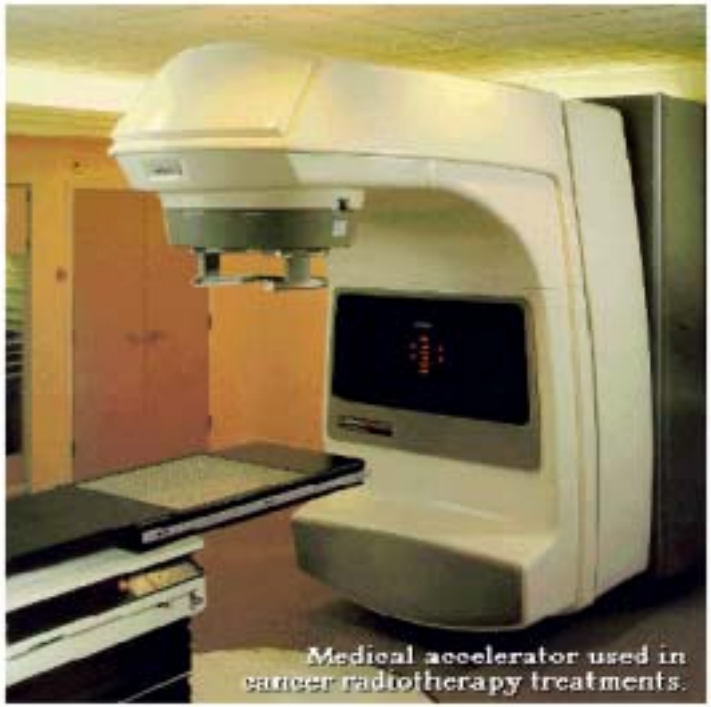

Photo courtesy of Varian Associates